Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	)	GN Docket No. 14-177
	)	
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	)	IB Docket No. 15-256
	)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664
	)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)	WT Docket No. 10-112
	)	
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations	)	IB Docket No. 97-95

To: The Commission

REPLY COMMENTS OF
THE BOEING COMPANY

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SUMMARY

Broadband satellites continue to serve a critical and irreplaceable role towards ensuring that very high data rate Internet services are equally available to all Americans, including those in the most rural and remote portions of the United States. In order for broadband satellite systems to adequately serve these populations, satellite operators will require significant access to V-band spectrum, including 5 GHz of downlink spectrum in the 37.5-42.5 GHz band and 5 GHz of uplink spectrum in the 47.2-50.2 and 50.4-52.4 GHz bands. Fortunately, satellite systems can share most of this spectrum with existing terrestrial fixed and future mobile services.

As requested by the Commission's Further Notice, The Boeing Company ("Boeing") provided extensive technical analysis in its comments showing that broadband satellites can transmit to earth stations in the 37.5-40.0 ("37/39") GHz band at the power flux density ("PFD") levels maintained by the International Telecommunication Union ("ITU") without causing harmful interference to existing or future terrestrial uses of this spectrum. As a result, allowing satellite systems to communicate with end user terminals in the 37/39 GHz band at the ITU PFD levels (rather than current levels that are unnecessarily more restrictive) would be fully consistent with the Commission's identification of the 37/39 GHz band for its newly created Upper Microwave Flexible Use Service ("UMFUS").

Broadband satellite systems will also require unencumbered access to satellite uplink spectrum for end user terminal transmissions in the 47.2-50.2 ("47") GHz band. Most of this spectrum has long been identified by the Commission as primarily available for Earth-to-space links (i.e., earth station uplink operations) and the satellite communications industry has been designing next generation broadband networks in reliance on its use. Although UMFUS

systems may be able to operate in the 47 GHz band indoors, UMFUS operations cannot be permitted to impede the unfettered use of transmitting end user terminals in this spectrum.

Broadband satellite systems will also required unencumbered access to satellite uplink spectrum for end user terminal transmissions in the 47.2-50.2 ("47") GHz band. Most of this spectrum has long been identified by the Commission as primarily available for satellite Earth-to-space links and the satellite communications industry has been designing next generation broadband networks in reliance on its use. Although UMFUS systems may be able to operate in the 47 GHz band indoors, any identification for UMFUS in this spectrum must not impede the unfettered placement of transmitting satellite end user terminals on any building of a subscriber.

Finally, broadband satellite networks require a full 5 GHz of uplink spectrum for individually licensed gateway earth stations that will be used to support the forward link transmissions to end user receivers in the 37.5-42.5 GHz band. In the 47 GHz band, these gateways will be able to operate on a shared basis with transmitting satellite end user terminals. In the 50.4-52.4 GHz band, these individually licensed gateways will be able to operate on a coordinated basis with UMFUS. Boeing will locate its earth station gateways only in rural and remote areas outside the more populated locations where terrestrial 5G proponents have expressed interest in providing UMFUS. Therefore, coordination of Boeing's gateways with UMFUS systems (be they mobile or point-to-point) should not be difficult.

Given the critical need to address permanently the persistent digital divide that exists between the availability of high speed broadband in urban and non-urban areas, the Commission has a statutory mandate to take additional steps to ensure that broadband services are made available to consumers throughout the United States on a seamless and equitable basis. Satellite systems provide proven assurance of broadband availability to all Americans. The

Commission should therefore ensure that satellite operators have sufficient access to V-band spectrum to achieve the speed and throughput requirements for broadband into the future.

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To: The Commission

REPLY COMMENTS OF
THE BOEING COMPANY

The Boeing Company ("Boeing") provides these comments in response to the Commission's Further Notice of Proposed Rulemaking ("*Further Notice*") examining the use of

higher frequency bands for next-generation wireless services, including mobile, satellite and other uses.[1]

The satellite industry has presented a very strong record in this proceeding regarding the critical importance of preserving access to sufficient spectrum in the V-band to support the next generation of very high data rate broadband satellite services. The continued growth of the broadband satellite sector is critical because satellites provide broadband on a competitive basis to all consumers, not just those in heavily populated areas.

Surprisingly, some wireless industry interests question the importance of the V-band to the broadband satellite industry and raise doubts about the future growth of this critical industry segment. T-Mobile, for example, argues "there are no currently authorized FSS operations in the 47 GHz band, and none are expected."[2] Nokia expresses a similar view, urging the Commission to consider "the likelihood (or lack thereof) that satellite will actually deploy services in these bands."[3]

Such arguments are misguided given the comparative deployment histories of satellite versus terrestrial services in millimeter wave ("mmW") spectrum. For example, in the late-1990s, the Commission segmented the Ka-band between satellite and terrestrial broadband communications services. Two decades later, the satellite industry is making aggressive use of the Ka-band to provide broadband services directly to consumers. In contrast, the terrestrial portion of the Ka-band—designated for the Local Multipoint Distribution Service ("LMDS")—

[1] *See* Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177 *et al.*, *Report and Order and Further Notice of Proposed Rulemaking*, FCC 16-89 (July 14, 2016) ("*Report and Order*" or "*Further Notice*").

[2] Comments of T-Mobile, GN Docket No. 14-177 *et al.*, at 17 (Sept. 30, 2016) ("*T-Mobile Comments*").

[3] Comments of Nokia, GN Docket No. 14-177 *et al.*, at 8 (Sept. 30, 2016) ("*Nokia Comments*").

has not been built out significantly.[4] It is largely due to this lackluster terrestrial build out that the Commission identified the 28 GHz band as potentially available for UMFUS. A similar conclusion can be reached about the 39 GHz service,[5] the current licensees for which seem far more interested in converting their licenses to UMFUS (with newly extended build out milestones) rather than implementing the 39 GHz systems authorized by the Commission more than a decade ago.[6]

In contrast, the satellite industry is actively developing broadband satellite systems to operate in the V-band. Inmarsat, for example, launched a satellite in 2013 that included an experimental 48 GHz payload, and reports that it is "developing plans for future use of the 47.2-50.2 GHz band for innovative FSS."[7] O3b, which already operates a broadband non-geostationary satellite orbit ("NGSO") system in the Ka-band, explains that it "has long planned to use the entire 47 GHz Band for gateways to support growth of its global system beyond the

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[4] *See* Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177 *et al.*, *Further Notice of Proposed Rulemaking*, FCC 15-138, ¶ 25 (Oct. 23, 2015) (observing that "[o]f the 986 designated [LMDS] license areas (493 BTAs times two licenses per BTA), 416 areas have active licenses, which cover about 75 percent of the U.S. population").

[5] The Commission has observed that "[o]ut of 2,464 possible EA [39 GHz] licenses (14 channel pairs for each of 176 EAs), 859 are currently licensed. Other licenses were voluntarily cancelled or terminated for failure to meet substantial service requirements. The populations in licensed areas (both EA and RSA licenses) vary by channel, but in aggregate they cover about 49 percent of the U.S. population." Use of Spectrum Bands Above 24 GHz For Mobile Radio Services; Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands; Implementation of Section 309(j) of the Communications Act -- Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands; Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, FCC 14-154, *Notice of Inquiry*, 29 FCC Rcd 13020, ¶ 57 (2014).

[6] *See* 47 C.F.R. § 101.17; Public Notice, *39 GHz Band Auction Closes, Winning Bidders of 2,173 Licenses Announced*, DA 00-1035 (May 10, 2000).

[7] *See* Comments of Inmarsat, GN Docket No. 14-177 *et al.*, at 17 (Sept. 30, 2016) ("*Inmarsat Comments*").

capacity it can provide with beams in the available Ka-band spectrum."[8] EchoStar also indicates that it is "currently designing a new satellite capable of delivering over a terabit of capacity per second" which would operate in spectrum bands addressed in the Further Notice.[9] Finally, Boeing is seeking authority to launch and operate an NGSO system that would use 5 GHz of paired spectrum in the V-band to provide very high data rate services to consumers throughout the United States (and globally).

Notably, these satellite system designs, which are based on technologies that have been employed in government satellite systems for many years, are much further along in development than the plans of the wireless industry for UMFUS in the V-band. As wireless industry leaders acknowledge, "[a]lthough the millimeter wave bands hold great promise for supporting 5G systems, significant research and development must still be done before the spectrum can be put to mobile use."[10] Therefore the U.S. satellite industry fully expects that, just as it did in the Ka-band, it will continue to provide leadership and be the first mover in the V-band with respect to the provision of very high data rate broadband services to consumers. It is critical to the public interest for the Commission to support and encourage this effort by preserving sufficient spectrum in the V-band for broadband satellite use. As Boeing has explained, these V-band spectrum requirements include sufficient access to 5 GHz of paired spectrum, much of which can be shared with UMFUS.

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[8] Comments of O3b Limited, GN Docket No. 14-177 *et al.*, at 5-6 (Sept. 30, 2016) ("*O3b Comments*").

[9] Comments of Echostar, GN Docket No. 14-177 *et al.*, at 3 (Sept. 30, 2016) ("*Echostar Comments*").

[10] Comments of CTIA, GN Docket No. 14-177 *et al.*, at 9 (Sept. 30, 2016) ("*CTIA Comments*") (citing Verizon NPRM Comments GN Docket No. 14-177 *et al.*, at 10 (Jan. 28, 2016); AT&T NPRM Comments, GN Docket No. 14-177 *et al.*, at 21 (Jan. 28, 2016)) (explaining that additional research is required to leverage millimeter wave bands to support 5G systems).

I. THE FURTHER NOTICE COMMENTS DEMONSTRATE THE NEED FOR BROADBAND SATELLITE SYSTEMS TO HAVE SUFFICIENT ACCESS TO V-BAND SPECTRUM TO BRING 5G BROADBAND TO ALL AMERICANS

As Boeing documented in its Further Notice comments, consumer demand for broadband is increasing exponentially and all broadband communications services – including satellite – must be designed and accommodated with this growth in mind. CTIA argues that the broadband growth projections identified by Boeing in its Further Notice comments include all demand for broadband and not just for satellite-delivered broadband.[11] This distinction is irrelevant. In order to ensure that the broadband needs of all consumers are served, the Commission should promote the use of different delivery architectures, whether they involve fiber, terrestrial wireless, satellite, or other means. Only in this way can we ensure that competitive opportunities to receive broadband services are available to all Americans, not just those in urban centers.

Further, despite the Commission's best efforts, satellite-delivered broadband is likely to remain the only choice available for many consumers in rural and remote areas. The broadband requirements of these consumers are growing at the same pace as the broadband requirements of their urban counterparts, if not more so given the critical role of competitive broadband to access educational, medical, commercial, governmental and other national infrastructure that is more readily accessible in urban areas. Therefore, the delivery infrastructure used to serve these consumers must be designed to address these critical needs and keep pace with expanding demand.

Fundamentally, 5G will not be solely a terrestrial wireless offering, but a broadband capability that will be delivered through multiple technologies. As Inmarsat emphasized in its

[11] Opposition to Petition for Rulemaking of CTIA, RM-11773, at 3 n.6 (Oct. 17, 2016).

comments, "there is no 5G future without satellite. Satellite connectivity, with its ubiquity, reliability, versatility, and increasing capacity, will be essential to creating this seamless connectivity experience."[12]

The critical need for broadband satellite systems to extend the reach of 5G coverage is emphasized by the Further Notice comments of 5G proponents. These parties are clearly in consensus in advising the Commission that UMFUS will primarily be used as an overlay to existing cellular networks to provide additional capacity in very congested environments and not, as the Commission has hoped, to expand network coverage. As CTIA explains in its Further Notice comments, "[w]hile the millimeter wave bands will help strengthen 5G network *capacity*, mid- and low-band spectrum will continue to drive network *coverage*."[13] Described differently by Qualcomm, "5G operations in spectrum bands above 24 GHz will provide ultra-high-speed service in *high-traffic* areas, supplementing 5G and 4G services that use sub-6 GHz spectrum to provide *coast-to-coast* connectivity."[14] Or as Huawei explains, "the high density traffic levels for which the mmW channels are planned are not well-suited for general wide area mobile coverage (such as that provided by current low frequency, i.e., < 3.6 GHz cellular systems)."[15]

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[12] *Inmarsat Comments* at 5. Inmarsat identifies a number of examples of satellite support for 5G services including: (i) high-bandwidth content and services directly to homes, planes, and people on the move; (ii) backhaul for 5G networks; (iii) data broadcast solutions; and (iv) delivery and augmentation of global navigation satellite services ("GNSS"). *Id.*

[13] *CTIA Comments* at 3 (*emphasis added*).

[14] Comments of Qualcomm Incorporated, GN Docket No. 14-177 *et al.*, at 4 (Sept. 30, 2016) ("*Qualcomm Comments*") (*emphasis added*). Qualcomm further explains that "base stations supporting bands above 24 GHz will likely have very small coverage areas and limited geographic coverage even in the aggregate." *Id.* at 13.

[15] Comments of Huawei Technologies, Inc. (USA) and Huawei Technologies Co., Ltd., GN Docket No. 14-177 *et al.*, at 13 (Sept. 30, 2016) ("*Huawei Comments*").

The Commission should therefore recognize that, while mmW spectrum may provide important opportunities for high-density broadband deployment, "[t]he high frequency spectrum contemplated in the FNPRM alone is not an all-purpose solution to the spectrum front confronting wireless providers."[16] Instead, "[m]obile operators are likely to deploy 5G services through small cells in select locations and markets, rather than universally."[17] These uniform assessments by 5G proponents reinforce the prior conclusions of CTIA that UMFUS is "unlikely to deliver extensive coverage in a market but instead will be best suited . . . in densely populated areas"[18] and will be used "primarily for adding capacity and high-speed data"[19] to existing networks in areas "with the greatest population density."[20]

Given these facts, the Commission must further its statutory mandate "to make available, so far as possible, to all the people of the United States . . . rapid, efficient, Nation-wide, and world-wide" communications services[21] and "the equitable distribution of radio service

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[16] Comments of AT&T, GN Docket No. 14-177 *et al.*, at 4 (Sept. 30, 2016) ("*AT&T Comments*"). AT&T further explains that "5G deployments will be driven by small cell network builds, meaning that urban and rural use cases may differ significantly" and "[w]ithout additional spectrum, particularly spectrum below 6 GHz, wireless coverage and capacity may fall behind." *Id.* at 4, 7.

[17] Comments of Microsoft Corporation, GN Docket No. 14-177 *et al.*, at 14 (Sept. 30, 2016) ("*Microsoft Comments*").

[18] Letter from Scott K. Bergmann, Vice President, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.*, at 2 (May 20, 2016) ("*May 20 CTIA Letter*").

[19] Letter from Brian M. Josef, Assistant Vice President, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.*, at 2 (May 24, 2016).

[20] *May 20 CTIA Letter* at 2.

[21] 47 U.S.C. § 151.

throughout the nation."[22] Pursuant to Section 254(b)(7) of the Communications Act,[23] the Commission has adopted "access to advanced services" as a principle on which it has based its universal service policies. The Commission did so after finding that providing support for broadband networks will further the statutory requirements to ensure that consumers in rural, insular and high-cost areas should have access to "advanced telecommunications and information services . . . that are reasonably comparable to those services provided in urban areas,"[24] and that "[a]ccess to advanced telecommunications and information services should be provided in all regions of the Nation."[25]

As part of its efforts to implement this principle, the Commission created the Connect America Fund ("CAF")[26] and recently adopted initial rules governing public interest obligations and eligibility for the upcoming CAF Phase II universal service competitive bidding process. Through this upcoming auction, the Commission intends to distribute up to $215 million in annual high-cost support for the deployment of broadband in rural and high-cost areas over a ten-year period.[27] That Order established eight sets of broadband performance standards: four speed

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[22] 47 U.S.C. § 307(b).

[23] 47 U.S.C. § 254(b)(7).

[24] 47 U.S.C. § 254(b)(3).

[25] 47 U.S.C. § 254(b)(2); *see* Connect America Fund, WC Docket No. 10-90, *Report and Order and Further Notice of Proposed Rulemaking*, FCC 11-161, 26 FCC Rcd 17663, ¶¶ 44-45 (2011) ("*USF/ICC Transformation Order*").

[26] *Id.*, ¶¶ 115 *et seq.*

[27] Connect America Fund, WC Docket No. 10-90, *Report and Order and Further Notice of Proposed Rulemaking*, FCC 16-64, 31 FCC Rcd 5949, ¶ 79 (2016) (setting the $215 million annual budget).

tiers, each with high- and low-latency alternatives,[28] in an effort to "provid[e] sufficient granularity with respect to the performance characteristics of broadband offerings, while maintaining an auction design that will encourage a broad range of providers to participate in the auction."[29]

Operators of V-band NGSO satellite platforms are perhaps best positioned to participate in the CAF Phase II auction as competitors in the high-speed, low-latency speed tiers, as their constellations will have sufficiently high capacity, low latency, and ubiquitous coverage to offer nationwide broadband service meeting the CAF Phase II requirements. The two primary impediments to the participation of satellite-based service providers in the CAF Phase II auction are: the capacity limitations of prior-generation satellite networks that lack sufficient spectrum access to reliably meet the Commission's 150 GB monthly minimum usage allowance,[30] and the transmission delay that exists for geostationary satellite orbit ("GSO") systems providing certain latency-sensitive applications.[31] The Commission can successfully address both of these impediments by providing NGSO satellite platforms with adequate access to sufficient V-band spectrum to provide very high data rate, low latency, broadband services.

II. OPPONENTS OF SATELLITE DOWNLINKS IN THE 37/39 GHZ BAND MISINTERPRET BOEING'S SPECTRUM SHARING ANALYSIS

The Further Notice requested detailed analysis on the potential for satellite systems to operate space-to-Earth transmissions in the 37/39 GHz band at the higher PFD levels authorized

[28] *Id.*, ¶ 15.

[29] *Id.*, ¶17.

[30] *Id.*, ¶ 22.

[31] *Id.*, ¶ 30.

by the International Telecommunication Union ("ITU"). Boeing responded to this invitation by providing extensive technical analysis that showed that the operations of multiple satellite in the 37/39 GHz band at the higher ITU power levels, even assuming pathological worst case conditions, would not result in appreciable interference to existing or future terrestrial systems. Boeing's analysis demonstrated that satellite operations at the higher PFD levels would be consistent with the Commission's identification for UMFUS in the 37/39 GHz band.

Other parties also filed comments on September 30 addressing the potential for satellite systems to operate in the 37/39 GHz band. Since September 30, Boeing has proactively engaged with these commenters in conference calls to explain Boeing's method of analysis and the assumptions employed. Boeing has also gained additional insight into the comments of other parties and compiled additional UMFUS use cases to use for further assessments of downlink sharing conditions. This additional analysis is ongoing and Boeing's reply comments address herein only the September 30 comments of other parties, many of which were discussed during the technical exchange conference calls between the parties.

A. Boeing's 37/39 GHz Analyses Included Extreme Worst-Case Sharing Conditions for UMFUS Receivers

T-Mobile suggests in its Further Notice comments that Boeing's analysis relies upon 5G base stations having at least 20 dB of isolation from satellite downlink transmissions, and argues that Boeing ignores potential steering of base station beams towards buildings or other paths.[32] Understandably, since T-Mobile's comments were filed on the same day as Boeing's, these comments do not accurately reflect the analysis that Boeing included in its Further Notice comments. T-Mobile's comments also fail to fully apprehend the analysis that Boeing

[32] *T-Mobile Comments* at 29.

submitted on July 7, 2016 to the Commission[33] in response to similar arguments that had been raised by Straight Path.[34]

Boeing's analyses employed the 3GPP antenna modeling recommendations[35] and included cases that used both 'correct' beam steering of end user devices and base stations and also used full-sector 'random' beam steering.[36] This worst case approach resulted in analyses that estimated interference in both typical and non-typical operations; for example, the random base station steering includes all possible paths such as multipath 'ray tracing' of possible higher gain reflected signals from a 5G user. Further, the analyses that Boeing provided in its Further Notice comments considered the effect of potential errors in the 5G beam forming process,[37] and fully encompassed potential interference levels for smaller subarrays (*i.e.*, 4x4) that might be used within a larger array beam forming process.[38] Such cases are conservatively represented by the UMFUS 'handset' cases, where similar beams are analyzed with mispointing directly towards the transmitting satellite.

It is apparent from these analyses that low-gain beams that provide limited isolation do not suffer from high interference due to their low directivity and, likewise, beams with sufficient

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[33] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.*, at Attachment 1 (July 7, 2016).

[34] *See* Letter from Davidi Jonas, CEO and President, Straight Path Communications, Inc., to Marlene H. Dortch, Federal Communications Commission, GN Docket No. 14-177 *et al.* (June 23, 2016).

[35] *See* Comments of The Boeing Company, GN Docket No. 14-177 *et al.*, at 32-33 and Table V-4 (Sept. 30, 2016) ("*Boeing Comments*").

[36] *See id.* at 36, Table V-5.

[37] *See id.* at 40.

[38] *See id.* at 32-33 and Table V-4.

directivity to provide 5G performance will provide higher sidelobe isolation and will have extremely low probability of beam pointing overlaps with any transient satellite interference events. Any interference introduced into the beam forming process with lower levels of gain remains similarly close to the noise floor and a 5G system will have no difficulty detecting the uniquely modulated 5G signals versus uncorrelated satellite signals.

B. The Minimal Impact of NGSO Satellite Operations at the ITU PFD Levels Will Not Restrict UMFUS Signal Range on System Configurations

In its Further Notice comments, Straight Path references its January 2016 analysis of satellite downlink transmissions in the 37/39 GHz band in which Straight Path assumed the simultaneous operation of three satellites transmitting signals at the maximum ITU PFD levels directly into an UMFUS receiver's peak of beam.[39] Such a situation is geometrically impossible for satellites because satellite operators employ diversity between the orbital locations of different satellites to prevent such combining and interference from multiple satellites or satellite systems into a single ground location.

The aggregate ePFD approach proposed by Boeing in its Further Notice comments correctly accounts for multiple signal arrivals and precludes this outcome. Further, the analysis that was included in Boeing's Further Notice comments relied on actual anticipated operations of a satellite system using power control to vary its PFD from lower levels used in clear weather cases (such as -117 dBW/m^2/MHz) up to the ITU PFD limit.[40] Boeing's results demonstrate that the already minimal impacts estimated in Boeing's June 7, 2016 *ex parte* analyses (*i.e.*, 0.2

[39] *See* Comments of Straight Path, GN Docket No. 14-177 *et al.*, at 14 (Sept. 30, 2016) ("*Straight Path Comments*") (*citing* Comments of Straight Path Communications, Inc., GN Docket No. 14-177 *et al.*, at 30-37 (Jan. 27, 2016)).

[40] *See Boeing Comments* at 26-30.

to 0.6 dB) will indeed occur very rarely (well under 1 percent of the time) when assessed against a large variety of UMFUS deployments.[41] Further, this "1 percent" of the time is an overly conservative estimate due to the assumption of rain conditions mixed with clear-sky to the UMFUS victim user.[42] The obvious conclusion is that NGSO FSS interference does not represent a significant or continuous degradation to UMFUS operations, nor would it harm investment in UMFUS systems, as claimed by Straight Path.

C. Boeing's Analysis Appropriately Modeled UMFUS Base Station Operations, Including With Upward Pointing Antennas

T-Mobile acknowledged in its Further Notice comments that UMFUS base station beams pointing upwards towards large buildings will be protected from satellite downlink transmissions by those building structures.[43] T-Mobile, however, then asserts that "for rural scenarios or suburban scenarios with smaller buildings, this may not be the case."[44]

Indeed, although the satellite signal attenuation resulting from blockage by tall buildings will likely be lower in scenarios with smaller buildings or with more broadly separated suburban structures, the 5G user elevation angles that will be needed to serve those buildings will correspondingly decrease, providing for higher sidelobe isolation for all operating 5G links. The cases discussed below further illustrate these relationships. Case A shown in Figure C-1 illustrates a tall building being serviced externally by various base stations at low heights. The

[41] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.*, at Attachment 1 (June 7, 2016); *see also Boeing Comments* at 27.

[42] *See Boeing Comments* at 29-31.

[43] *T-Mobile Comments* at 29.

[44] *See id.* at 29.

building depicted is 55 meters in height, which represents a 10 story building and is as tall, or taller than, 99.8 percent of all buildings in the United States.[45]

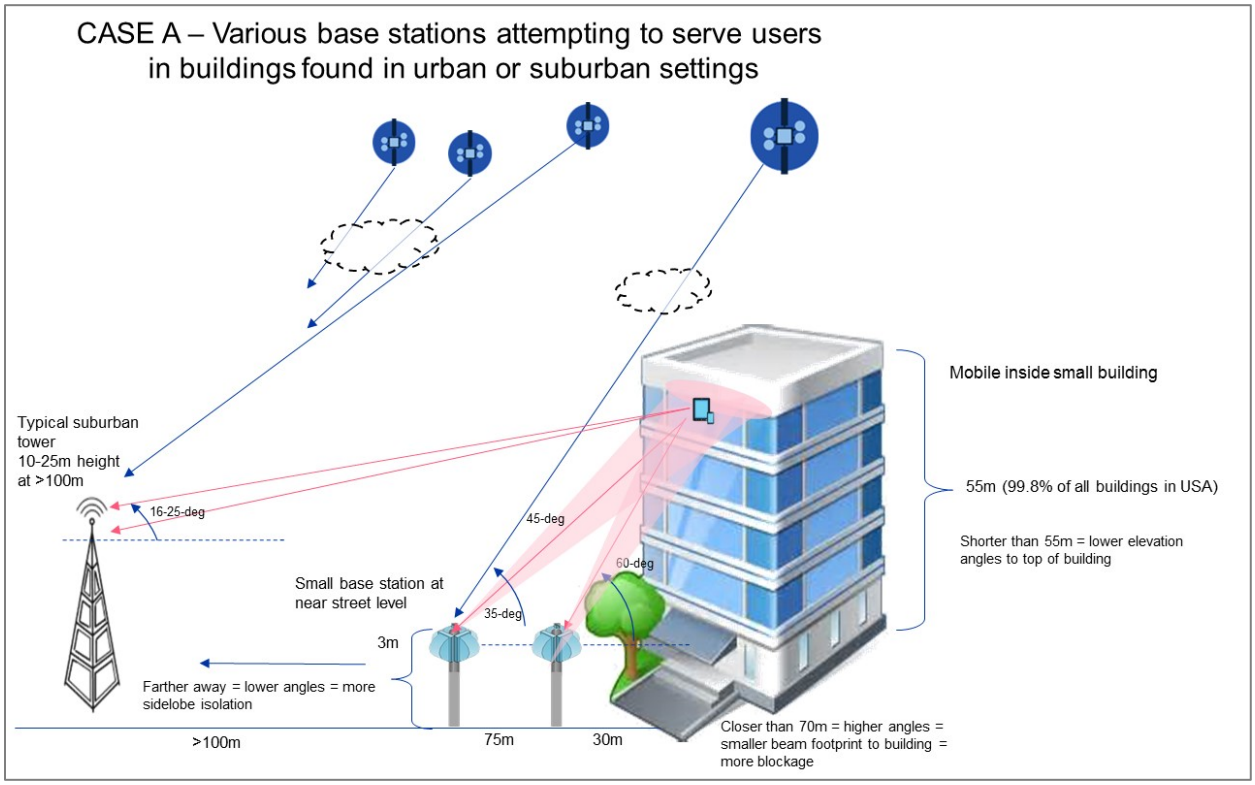

Figure C-1 – Coverage of users in tall buildings from either close-in base stations (urban canyon) or typical suburban cell tower(s)

In Case A, an UMFUS base station is initially placed outside on a three meter structure at approximately 30 to 75 meters away from the building. The resulting upward transmission paths to the building would reach elevation angles of 45 to 60 degrees. As such, this is representative of an urban canyon scenario with even deeper canyons and taller buildings than the 3GPP Urban Micro scenario that was discussed in Boeing's Further Notice comments.[46] As

[45] Council on Tall Buildings and Urban Habitat (CTBUH) Building Height calculations, found at http://www.ctbuh.org/TallBuildings/HeightStatistics/HeightCalculator/tabid/1007/language/en-GB/Default.aspx ; 2012 CBECS at Table B.1, found at http://www.eia.gov/consumption/commercial/data/2012/bc/pdf/b1-b2.pdf.

[46] *See Boeing Comments* at 34-35.

Boeing explained in its Further Notice comments, such configurations will be adequately protected from interference from satellites transmitting from overhead.[47]

Figure C-1 also depicts an alternative approach to serving this same building. Specifically, T-Mobile suggested in its Further Notice comments that a building may be served by an upwardly pointing UMFUS base station that is too distant from the building to benefit from the building's natural shielding from satellite downward transmissions.[48] For example, a typical suburban base station may be around 10 to 25 meters in height and could be more than 100 meters, or up to one kilometer, from the building being served. As depicted in Figure C-1, in this scenario the upward elevation angle of the UMFUS transmission is significantly decreased (down to levels of around 16 to 25 degrees) and thus adequate isolation will exist to protect such configurations from satellite transmissions from overhead. In fact, Boeing's Further Notice comments demonstrate that UMFUS base stations can operate in directions up to 60 degrees skywards and still experience link degradations (noise increases) of less than 0.5 to 0.6 dB.[49]

Case B, in Figure C-2 below, reverses the situation and assumes that a 5G base station is placed on top of a tall building in order to serve the surrounding area. This is clearly the more common configuration based on existing wireless network deployments in urban and suburban communities. Figure C-2 shows a variety of mobile and fixed customer premises equipment ("CPE") cases being served by a UMFUS base station on a 55 meter building (again, representing 99.8 percent of all buildings in the United States).

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[47] *See id.* at 37, Table V-6.

[48] *See T-Mobile Comments* at 29 (arguing that "for rural scenarios or suburban scenarios with smaller buildings" shielding may not result).

[49] *See Boeing Comments* at 37, Table V-6.

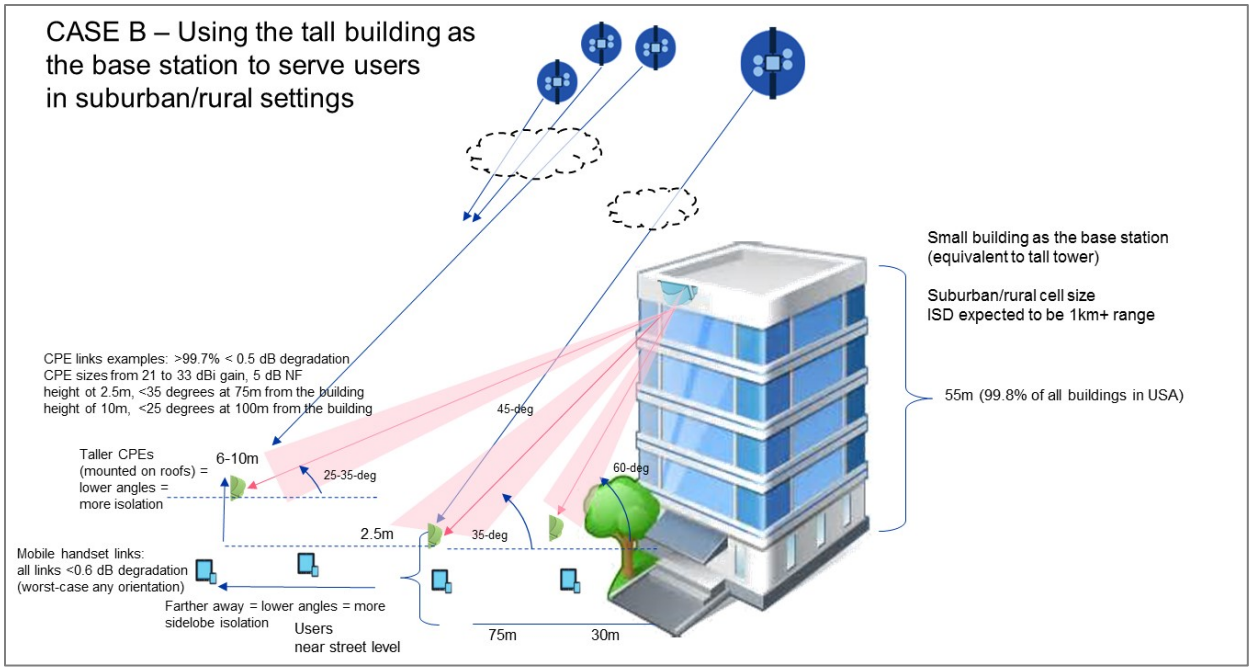

Figure C-2 – Using typical tall buildings as the base station in urban or suburban coverage settings

All of the cases shown in Figure C-2 were encompassed by the scenarios included in Boeing's Further Notice comments.[50] The mobile users (which will be deployed anywhere) experience less than 0.6 dB of signal degradation, which largely results from Boeing's very worst-case assumptions of mobile user antenna mispointing toward the satellites, rather than toward the desired UMFUS base station.[51]

The fixed CPE scenarios employ high gain antennas similar to those employed on the base stations and experience less than 0.5 dB degradations as well.[52] In fact, for typical CPEs, mounted on structures that are 3 to 10 meters in height, the resulting worst case degradations (*i.e.*, during rain events) from satellite downlinks at the higher ITU PFD levels are less than 0.5 dB with a confidence level of 99.7 percent. Further, the level of signal degradation will decrease

[50] *See id.* at 36, Table V-5.

[51] *See id.*

[52] *See id.* at 27, Table V-1.

further (to less than 0.5 dB) as the fixed CPE is positioned further away from the base station (such as greater than 75 meters) and thus benefits from greater signal isolation from the satellites as it communicates with UMFUS base stations at even lower elevation angles. Thus, assuming an UMFUS base station serving a suburban cell of 1 kilometer radius, only 1 percent of the fixed CPEs in that cell (those closest to the base station) would experience degradations of as high as 0.5 dB and those CPE would experience such degradations less than 0.3 percent of the time and only when it is raining. Given this analysis (which was addressed in more detail in Boeing's Further Notice comments[53]), it is evident that the proposed operation of satellite downlink transmissions in the 37/39 GHz band at the higher ITU PFD levels will not impede UMFUS licensees from configuring their networks to include upwardly pointing base stations, or upwardly pointing end user receivers, since such configurations will experience very minimal, if any, interference from the satellite transmissions.

D. The Use of an Aggregate ePFD Approach Appropriately Reflects the Contributions of All Visible Satellites

T-Mobile again asserts in its Further Notice comments that Boeing's analysis is incomplete, arguing that "Boeing proposed a large constellation of satellites" and that "[t]he satellite was assumed to be at an elevation angle greater than 45 degrees," but that the "satellites could be at much lower elevation angles."[54] T-Mobile appears to disregard that none of Boeing's satellites will radiate any beams at an elevation angle below 45 degrees (as viewed from the Earth).[55] The only emissions from satellites at an elevation angle below 45 degrees

[53] *See id.* at 24-40.

[54] *See T-Mobile Comments* at 29-30.

[55] *See, e.g., Boeing Comments* at 15, 18 and 34.

are sidelobe emissions, which would be far below the level of contributions from the operational spacecraft beams and are further attenuated by range losses, atmospheric losses, and other mitigating factors as elevation angles decrease. All of the emissions from satellites visible above the horizon, along with their planned operating levels, are included in the ePFD regulations proposed by Boeing and are used in Boeing's downlink interference analyses.[56] It is not necessary to impose elevation angle operational regulations on satellite systems, as the emissions limits (both single beam and entire constellation aggregate ePFD) serve to fulfill this purpose.

E. The Commission Should Update its Current Satellite Transmission Regulations for the 37/39 GHz band to Reflect Boeing's Aggregate ePFD Proposal

FiberTower argues in its Further Notice comments that current regulations, depending on its interpretation, may not be adequate to protect the existing fixed service ("FS") or planned UMFUS services.[57] FiberTower explains that "[f]uture high-density mobile services, whose base stations will operate on principles almost identical to fixed service point-to-multipoint base stations, require the same protections from harmful interference.[58] In fact, UMFUS operations may require more robust protections from FSS interference than those currently in place."[59]

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[56] *See id.* at 41.

[57] Comments of FiberTower, GN Docket No. 14-177 *et al.*, at 5 (Sept. 30, 2016) ("*FiberTower Comments*").

[58] *Id.*

[59] *Id.*

In their Further Notice comments, multiple parties such as the National Spectrum Management Association ("NSMA"),[60] Straight Path,[61] and FiberTower[62] also reference a particular summary by PHAZR assessing potential interference from FSS emissions permitted by existing ITU Radio Regulations into various 5G equipment classes.[63] The referenced PHAZR analyses assume 5G UMFUS equipment characteristics that are both unlikely and highly optimistic. In particular, the PHAZR analyses assume very low noise temperatures (-114 dBm/MHz, or 3 dB or less noise figure), which are far below values suggested by others for 5G devices and effectively include no background temperature.[64] PHAZR also included a large antenna (1 square meter) (along with a 0.1 square meter base station antenna and a 0.01 square meter mobile antenna) with no aperture inefficiencies or losses and thereby resulting in a large I/N value for a flux density arriving on boresight.[65]

Such analyses are overly pessimistic and this approach, if followed, would essentially lead to the inability of UMFUS to share the frequency band with all other services, including terrestrial FS or other UMFUS systems. These analyses would also result in the inability to meet the -77 dBm/m^2/MHz (-107 dBW/m^2/MHz) levels imposed for FSS gateway coordination or for

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[60] *See* Comments of the National Spectrum Management Association, GN Docket No. 14-177 *et al.*, at 5 (Sept. 30, 2016).

[61] *See Straight Path Comments* at 14.

[62] *See FiberTower Comments* 5.

[63] *See* Letter from Farooq Khan, CEO, PHAZR, to Marlene H. Dortch, Secretary, Federal Communications Commission, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 (July 6, 2016) ("*PHAZR Letter*").

[64] *See id.*, at Attachment 1 at 2-5.

[65] *See id.*

coordination between UMFUS licensees serving different geographic areas as required in the Order.

As Boeing noted in its Further Notice comments, the Commission clearly assumes that the inherent capabilities of new mmW systems will include narrow beams and beam forming, and the Commission has appropriately relied on statistical analyses rather than pure worst case to determine the acceptable levels of interference, including tolerable levels of interference that are often up to 0 dB I/N.[66] Efficient use of spectrum for multiple technologies requires the systems that share the band to incorporate sufficient robustness to enable good faith coordination. The systems being designed and potentially fielded by 5G proponents and equipment manufacturers all include multiple mechanisms for interference management, though the analyses supplied by some of their proponents do not reflect these capabilities.

Even existing FS systems, which were described by FiberTower as "brittle" and leaving "no room for increased satellite power levels"[67], employ modern adaptive coding and modulation techniques that enable links to sense and adapt to changing link conditions including interference. As Boeing has demonstrated, the magnitude of NGSO interference is below 0.5 dB when the satellites are operating up to the ITU PFD limits, and the probability of such events is well below 1 percent (during high rain fades only, essentially < 0.1%) and decreases further with increased antenna size. As FiberTower admits, FS and UMFUS base stations share similar characteristics, namely narrow beams with high gain, but also low sidelobes.[68] Boeing's proposed additional

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[66] *See Report and Order*, ¶¶ 294, 312; *Boeing Comments* at 20 n.34, 48 n.59 and n.60.

[67] *FiberTower Comments* at 4.

[68] *See id.* at 5.

aggregate ePFD regulations, which are specific to NGSO systems, can provide protection with high confidence for both UMFUS and FS deployments.

III. DEMONSTRATED DEMAND DOES EXIST TO WARRANT SATELLITE END USER RECEIVERS IN THE 37/39 GHZ BAND

As Boeing and other satellite interests have clearly shown in their comments, there is a significant requirement for additional downlink spectrum beyond the 40.0-42.0 GHz band to support forward link data requirements of end users. As Boeing has also demonstrated, satellite end user terminals can receive signals in the 37/39 GHz band on an opportunistic basis, imposing no burden on UMFUS licensees to accommodate satellite end user terminal operations. In fact, UMFUS licensees in the 37/39 GHz band will have no idea where satellite end user terminals are located.

Despite this fact, some parties continue to assert that opening the 37/39 GHz band to satellite end user terminals could harm UMFUS operations. T-Mobile, for example, argues that allowing "ubiquitous satellite user equipment means that the satellite beams would need to provide coverage wherever the user terminals are located, which would result in unpredictable interference to 5G base stations and mobile receivers."[69] Ericsson also argues that "[t]he deployment of satellite user terminals would raise interference concerns from downlink operations into terrestrial mobiles."[70] Finally, Straight Path argues that "[t]he Report and Order correctly establishes exclusion zones for a limited number of satellite earth stations.

[69] *T-Mobile Comments* at 30.

[70] *See* Comments of Ericsson, GN Docket No. 14-177 *et al.*, at 20 (Sept. 30, 2016) ("*Ericsson Comments*").

Allowing unlimited satellite user equipment in the 37 GHz and 39 GHz bands, even with secondary status, will pose a significant business risk for 5G services in this band."[71]

Each of these parties misunderstands the nature of satellite system operations. Satellites have long been authorized to operate individually licensed satellite gateways in the 37/39 GHz band. Satellite downlink transmissions to these gateways will illuminate much, if not all, of the United States regardless of where the gateways are actually located within an EA or PEA. Exclusion zones for FSS gateways operating in this receive band apply only to the interference generated by UMFUS services into those gateways, and not vice-versa. Therefore, the addition of satellite end user terminals in the 37/39 GHz band will not necessitate an increase in satellite downlink transmissions in this spectrum, it will only change the number of terminals (be they individually licensed or not) that are able to passively receive the signals.

Ericsson then reverses the argument, focusing not on interference to UMFUS (which will not exist), but on interference to satellite end user terminals. Ericsson posits that "if the Commission were to allow voluntary secondary deployment of user terminals, and interference were to occur, it may be difficult to shut down the operation of those user terminals, which would result in a loss of customer service."[72]

Ericsson's concern might be valid if satellite end user terminals lacked access to alternative spectrum in situations in which they receive excessive interference from UMFUS. As Boeing has repeatedly explained, however, (and as the Commission appears to acknowledge) satellite end user terminals will also require primary, unencumbered access to the 40.0-42.0 GHz band for downlink capacity. The 40.0-42.0 GHz band will therefore be

[71] *Straight Path Comments* at 15.

[72] *Ericsson Comments* at 21.

available both as the core spectrum to be used as a first option to fulfill the forward link capacity requirements of broadband satellite subscribers. It will also be available as a fallback for satellite end user terminals in locations that experience excessive interference from UMFUS in the 37/39 GHz band. This will fully alleviate Ericsson's concern about possibly suspending broadband satellite services to subscribers.

Straight Path further argues that UMFUS interference will likely prevent satellite end user terminals from ever receiving desired signals in the 37/39 GHz band.[73] Boeing believes that situations will only rarely exist in which satellite end user terminals are unable to receive signals in the 37/39 GHz band. 5G proponents, through 3GPP and other fora, have identified likely UMFUS deployment scenarios that are carefully designed to avoid both intra-system interference within each UMFUS cell and inter-system interference between UMFUS cells. The resulting network architecture and operational techniques that have been described by 5G proponents (usually involving the use of narrow beams, power control, and base station power levels well below 75 dBm) will not only serve to protect UMFUS operations, but will also protect satellite end user terminals that are receiving signals from satellites using the same spectrum.

Further, as Boeing has repeatedly explained, the advanced design of its NGSO satellite system includes beam forming, power control, adaptive modulation/coding, and dynamic time/frequency plan channel assignment techniques. The dynamic channel assignment techniques are identical to 5G system capabilities and can mitigate the impacts of terrestrial interference on FSS end user terminals. Given that 5G systems operate using these principles, which were relied upon extensively by the Commission in the Report and Order, the

[73] *Straight Path Comments* at 15.

Commission should maximize the efficient use of scarce V-band spectrum resources by authorizing satellite end user terminals to receive downlink transmissions in the 37/39 GHz band.

IV. THE COMMISSION MUST PRESERVE UNENCUMBERED USE OF THE 40.0-42.0 GHZ BAND BY BROADBAND SATELLITE SYSTEMS

Although outside the scope of the Further Notice, several wireless interests argue that the Commission should consider allowing UMFUS operations in the 40.0-42.0 GHz band on a shared basis with satellite systems.[74] As a starting point, Boeing emphasizes that the Commission appropriately excluded the 40.0-42.0 GHz band from the Further Notice in acknowledgement of its tremendous importance to the satellite communications industry. There are extensive plans to use the V-band for various types of broadband satellite systems, both GSO and NGSO, and for satellite feeder links and direct-to-user services. GSO satellite systems provide latency-insensitive broadband and video broadcast services in an extremely efficient and effective manner by reusing the same spectrum from different orbital locations along the GSO arc. Certain GSO FSS configurations, however, may not be able to incorporate the inherent mechanisms identified by Boeing to facilitate sharing between its NGSO system and UMFUS in the 37/39 GHz band such as operating only at higher elevation angles.

The Commission appears to have already recognized the importance of ensuring that the 40.0-42.0 GHz band is kept available for broadband satellite systems. The Commission wisely excluded the 40.0-42.0 GHz band from the scope of the *Further Notice*. Therefore, calls by some parties to consider allowing UMFUS in the 40.0-42.0 GHz band are clearly outside the scope of the current proceeding. Instead, Boeing fully supports unencumbered uses of the 40.0-

[74] *See CTIA Comments* at 13, *T-Mobile Comments* at 5, *Straight Path Comments* at 5-7, *Huawei Comments* at 6, *Ericsson Comments* at 11.

42.0 band for the wide variety of satellite purposes stated above, and urges the Commission to continue to exclude 40.0-42.0 GHz band from the significant amount of spectrum under consideration for UMFUS operations.

V. THE COMMISSION SHOULD MAKE AVAILABLE SUFFICIENT SPECTRUM IN THE 47 GHZ BAND FOR TRANSMITTING SATELLITE END USER TERMINALS

Boeing and other satellite industry participants have provided clear guidance to the Commission regarding the importance of ensuring that the 47 GHz band remains available on an unencumbered basis for Earth-to-space transmissions involving individually licensed earth stations and ubiquitously deployed end user terminals. The satellite industry has appropriately relied on repeated Commission assurances that the entire 47 GHz band would remain available for satellite use.[75] Specific examples of satellite industry initiatives using the 47 GHz band are detailed in the introduction to these comments.

Given the significant needs of broadband satellite systems for end user uplink spectrum in the 47 GHz band, the Further Notice identifies several options for spectrum sharing with UMFUS in this band. The Commission concurrently acknowledged, however, that "sharing

[75] *See, e.g.,* Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.0-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, IB Docket No. 97-95, *Report and Order*, FCC 98-336, 13 FCC Rcd 24649 (1998) (designating the 48.2-50.2 GHz band for satellite uplinks); Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, FC 03-296, *Second Report and Order*, 18 FCC Rcd 25428, 25448 (2003) (explaining that the Commission will "allow gateway operations in 47.2-48.2 GHz FSS (Earth-to-space) band provided that the earth station downlink operations are also coordinated for use in the 37.5-40.0 GHz band").

between terrestrial mobile and FSS user equipment [in the 47 GHz band] is more complicated particularly when the FSS user equipment is transmitting."[76]

Boeing concurs with those parties that oppose the use of a Spectrum Access System ("SAS") to govern spectrum sharing in the 47 GHz band.[77] Such an approach will not provide satellite system operators with sufficient assurance that they will be able to locate transmitting end user terminals on the home or office of any subscriber wherever they are located, which is necessary to market a competitive broadband offering to consumers.[78]

Boeing, however, also opposes calls for segmentation of the 47 GHz band.[79] As Boeing explained in its Further Notice comments, Boeing will require unencumbered access to the entire 47 GHz band for transmitting end user terminals. The spectrum requirements of other satellite system operators must be accommodated in this spectrum as well.

Further, supporters of band segmentation seem to suggest that an equitable division be based solely on the 3 GHz of spectrum within the 47 GHz band,[80] without taking into account the nine other mmW spectrum bands that have been identified or proposed for UMFUS in this proceeding.[81] When all these spectrum bands are considered as a whole—as is required to

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[76] *Further Notice*, ¶ 411.

[77] *See, e.g., T-Mobile Comments at 16-18.*

[78] *See Boeing Comments* at 16.

[79] *See id.* at 17.

[80] *See, e.g., T-Mobile Comments at 17.*

[81] The adopted UMFUS spectrum bands include the 27.5-28.35 GHz ("28 GHz") band, the 37.5-38.6 GHz ("37 GHz") band, and the 38.6-40.0 GHz ("39 GHz") band, while the candidate UMFUS spectrum bands include the 24.25-24.45 GHz and 24.75-25.25 GHz band ("24 GHz band"), the 31.8-33.4 GHz ("31 GHz") band, the 42.0-42.5 GHz ("42 GHz") band, the 47.2-50.2 GHz ("47 GHz") band, the 50.4-52.6 GHz ("50 GHz") band, the 71-76 GHz ("70 GHz") band, and the 81-86 GHz ("80 GHz") band.

support reasoned decision making—the only appropriate conclusion is that the entire 47 GHz band should remain available for unencumbered satellite uplink transmissions and any use of the band by UMFUS should be on an opportunistic basis.

Fortunately, there are potential UMFUS applications that could operate successfully in the 47 GHz band on an opportunistic basis. For example, 5G proponents explain that "studies have confirmed the usefulness of mmW channels for indoor communications, particularly for offices and malls."[82] Given the significant signal attenuation that exists in the V-band as a result of customary building materials,[83] UMFUS devices operating indoors are exceedingly unlikely to experience interference from the upward transmissions of satellite end user terminals, which would be located outdoors. Therefore, although the record in this proceeding fully justifies an exclusive identification for transmitting satellite end user terminals in the 47 GHz band, Boeing acknowledges that spectrum sharing is possible as long as UMFUS operations are limited to an indoor basis.

VI. COORDINATION OF INDIVIDUALLY-LICENSED EARTH STATIONS IN THE 50 GHZ BANDS

A strong consensus appears evident in the Further Notice comments of 5G proponents and satellite interests regarding the use of a first-in-time coordination approach to address co-primary spectrum sharing between individually licensed gateway earth stations and UMFUS systems in the 50 GHz band. As Qualcomm explains, the use of a "first come, first serve basis

[82] *Huawei Comments* at 12 (citing Katsuyuki Haneda, *et al*., Indoor 5G 3GPP-like Channel Models for Office and Shopping Mall Environments, 2016 IEEE International Conference on Communications Workshops (May 2016), available at http://arxiv.org/pdf/1603.04079.pdf).

[83] *See, e.g., Microsoft Comments* at 11. Microsoft explains that "[b]ased on an ITU report, it appears that 30 GHz is a breakpoint with respect to radio signal penetration through walls from outdoors to indoors." *Id.* (citing *Technical feasibility of IMT in bands above 6 GHz*, Report ITU-R M.2376-0, July 2015).

looks to be the most flexible and efficient approach" to assigning site-based priority between UMFUS systems and individually licensed satellite earth stations.[84] Hauwei also supports a coordination approach to spectrum sharing in the 50 GHz band, concluding that "[t]he key to success of sharing among both common and disparate services is the willingness of all parties to take coordinated action to share spectrum assignments."[85]

The Fixed Wireless Communications Coalition ("FWCC") also appears to support "bilateral frequency coordination," but raises questions about whether sufficient incentives would exist to ensure that coordinated systems are actually constructed and in operation.[86] FWCC notes that "the highly successful Part 25/Part 101 frequency coordination regime puts strict time limits on licensing after coordination, construction after licensing, and (as to the fixed service) loading after construction."[87] FWCC seeks assurance that similar requirements would be adopted for the 50 GHz band[88] and Boeing supports such restrictions.

Boeing further believes that satellite and 5G proponents should work together to forge the details of a coordination approach for the 50 GHz band taking into account the unique opportunities that mmW technologies present to facilitate sharing. As Qualcomm explains, in order to develop coordination requirements between UMFUS and satellite earth stations, consideration should be given to

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[84] *Qualcomm Comments* at 9.

[85] *Huawei Comments* at 8.

[86] *See* Comments of The Fixed Wireless Communications Coalition, GN Docket No. 14-177 *et al.*, at 8 (Sept. 30, 2016).

[87] *Id.*

[88] *See id.*

> the unique characteristics of millimeter wave RF propagation and novel interference conditions these bands experience to enable successful spectrum sharing with satellite operations. For example, the average interference from a millimeter wave mobile handset and associated base station/small cell with a steerable antenna array is quite different from and varies instant to instant when compared to fixed operations in the millimeter wave bands or, for that matter, mobile operations in the sub-3 GHz range.[89]

Another equipment developer, Huawei, appears to concur, explaining "[t] he application of new technologies—beam forming, antennas and power-control, and dynamic operation, for example—will ensure the continuing enablement of new services and opportunities without a universal need for exclusivity in all spectrum assignments."[90]

The need for a direct coordination approach is amplified when considering the difficulties of applying the restrictions that are proposed in the Further Notice for the siting of individually licensed satellite earth stations. The Further Notice appears to propose that such earth stations be permitted in the 47 GHz band subject to flux density levels of less than -77 dBW/m^2/MHz at a distance of 160 or 200 meters.[91] The Commission appears to have gleaned this limit based on analysis provided by the 5G Joint Filers.[92] As Boeing explained in its Further Notice comments, this approach will have serious shortcomings for both FSS and UMFUS licensees.[93] Multiple

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[89] *Qualcomm Comments* at 10. Qualcomm explains that it "believes that it may be possible to employ spectrum sharing techniques, such as those discussed []in Section II.D [of Qualcomm's comments], to avoid interference from FSS earth station transmissions." *Id.* at 11.

[90] *Huawei Comments* at 8.

[91] *See Further Notice*, ¶ 412 (proposing rules for individually licensed earth stations that are subject to the conditions and limitations the Commission adopted for the 28 GHz band).

[92] *Report and Order*, ¶¶ 310, 312 (citing to Letter from Joint Filers (AT&T, Nokia, T-Mobile, Samsung, and Verizon) to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.*, at 1 (May 6, 2016) ("*Joint Filers Letter*")).

[93] *Boeing Comments* at 20 n.34.

parties have submitted analysis suggesting that this coordination distance varies with propagation and line of sight ("LOS") conditions, with values ranging from 150 meters to more than 10 kilometers.[94] All of these analyses use the assumption of Fris equations and classic far-field antenna pattern coupling analyses, which are only valid in the far-field of both antenna systems.

FSS gateway earth stations typically employ much larger apertures to support the bandwidth and distances required for communications with NGSO and GSO satellites. The Report and Order relied on analyses by the 5G Joint Filers, which considered three classes of earth stations.[95] The largest earth station, Class 3, used 48 dBmi/MHz, which corresponds only to a 48 dBWi value for a 1 GHz gateway station and is far short of more typical values, such as 60 to 80 dBWi gateway EIRPs per GHz. For these large earth station aperture sizes, potential exclusion zones in the range of 200 meters, as suggested in the Report and Order, quickly violate the Fraunhofer distance of $(k*D^2/\lambda)$.[96] The analyses presented for both field intensity versus distance and antenna isolation (sidelobes) will not apply at this distance. For example, a 6 meter aperture at 28 GHz may require up to 1,680 meters before the far-field region applies. Likewise, a 3.5 meter aperture at 47 GHz (which has a similar electrical diameter) requires a 1,000 meter distance to ensure far-field field density is achieved along with expected sidelobe isolations. In addition, the propagation loss models relied upon in the Intel analysis to generate smaller distances, such as 150 meters, use non-line-of-sight ("NLOS") analyses which is

[94] *See Joint Filers Letter* at 1; *Sharing between FSS and 5G Systems at Frequencies Around 28 GHz*, Intel Corporation, at 7 (June 21, 2016), *included as attachment to* Letter from Peter Pitsch, *et al*., Intel Corporation, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.* (June 21, 2016) ("*Intel Study*").

[95] *See Joint Filers Letter,* Attachment 1 at 13, Table 3.

[96] Assuming that k=0.5 to 2, depending on the desired degree of convergence of the wavefront. *See* J.D. Kraus, *Antennas*, 2nd edition, at 809-811 (McGraw-Hill, Inc.); R.J. Johnson, *Antenna Engineering Handbook*, 3rd edition, at 1-10 through 1-12 (McGraw-Hill, Inc.).

inappropriate for rural settings.[97] Intel acknowledges that its analysis relied on a satellite earth station model described in ITU-R Recommendation P.452 and "due to the short distances involved, the appropriateness of the P.452 model for the case of interference into the 5G mobile station needs to be verified."[98] Similarly, the 3GPP channel modeling report computes the probability of clear LOS conditions in these rural settings to be greater than 83 percent for distances of less than 200 meters.[99] Samsung notes in one of its ex parte presentations that practical distances for a sample set of FSS earth stations will lie in the 1 to 5 kilometer range depending on the site characteristics and sidelobe gain toward the horizon.[100] Distances in the range of 1,000 meters and above are clearly more consistent with far-field assumptions as well as the actual distances achieved in rural exclusion zone analyses and should be used to develop a practical and implementable FSS gateway and UMFUS coordination approach.

As Boeing has repeatedly explained, Boeing plans to site its satellite earth station gateways in rural and remote areas of the country. This is consistent with the apparent goals of the *Joint Filers*, which observed that for Class 3 earth stations, "the limited number and rural locations of existing Class 3-type earth stations would not significantly impact 5G deployment"[101] As Boeing stated in its Further Notice comments, locating even large numbers

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[97] *See Intel Study* at 7.

[98] *Id.*

[99] *See* 3rd Generation Partnership Project Technical Specification, "Channel model for frequency spectrum above 6 GHz (Release 14)," 3GPP TR 38.900 V1.0.0 (2016-06), Section 7.4.2 LOS probability.

[100] *See* Letter from Robert Kubik, Ph.D., Director, Public Policy, Engineering and Technology, Samsung Electronics America, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.*, Attachment 1 at 14-17 (May 9, 2016).

[101] *Joint Filers Letter* at 4.

of gateways in such a manner is possible, and the potential interference would only affect about 0.1 percent of the U.S. population.[102] Boeing's gateway deployment requirements, however, will not be able to comply with the adopted PFD restrictions, a limit of 1 or 3 sites per county or PEA, or a restriction of affecting no more that 0.1 percent of the population of each county or PEA.[103]

Therefore, Boeing urges the Commission to refrain from imposing similar arbitrary limits on satellite earth station deployment in the 47 or 50 GHz bands. The necessary analyses for coordination measures between individually licensed satellite earth stations and UMFUS systems are still in development and the record in this proceeding regarding appropriate interference criteria and practical implementations of those criteria is far from complete.[104] The direct coordination method, which defines locations and exclusion distances via direct dialog between FSS and UMFUS licensees, provides a much better solution for sharing of UMFUS services with FSS gateway earth stations, allowing the UMFUS providers and FSS operators to coordinate individually licensed FSS satellite earth stations on a co-primary, first-in-time basis.

VII. CONCLUSION

For the reasons stated herein, the Commission should resolve to address the persistent digital divide by ensuring that broadband satellite systems have access to sufficient V-band spectrum to satisfy the broadband speed and throughput requirements of Americans, regardless of where they are located. The satellite industry requires access to 5 GHz of paired spectrum in

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[102] *Boeing Comments* at 20.

[103] *See, e.g., id.* at 19-20.

[104] *Report and Order*, ¶ 54 n.120 (requesting further assessments in interference zone calculations and percent populations in EA/PEAs).

the V-band, including—for downlinks—opportunistic access to the 37/39 GHz and 42.0-42.5 GHz bands and unencumbered primary access to the 40.0-42.0 GHz band, and—for uplinks—unencumbered primary access to the 47 GHz band and co-primary coordinated access to the 50.4-52.4 GHz band. The Commission's public interest obligation to ensure that broadband services are made equally available to all Americans necessitates this result.

Respectfully submitted,

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